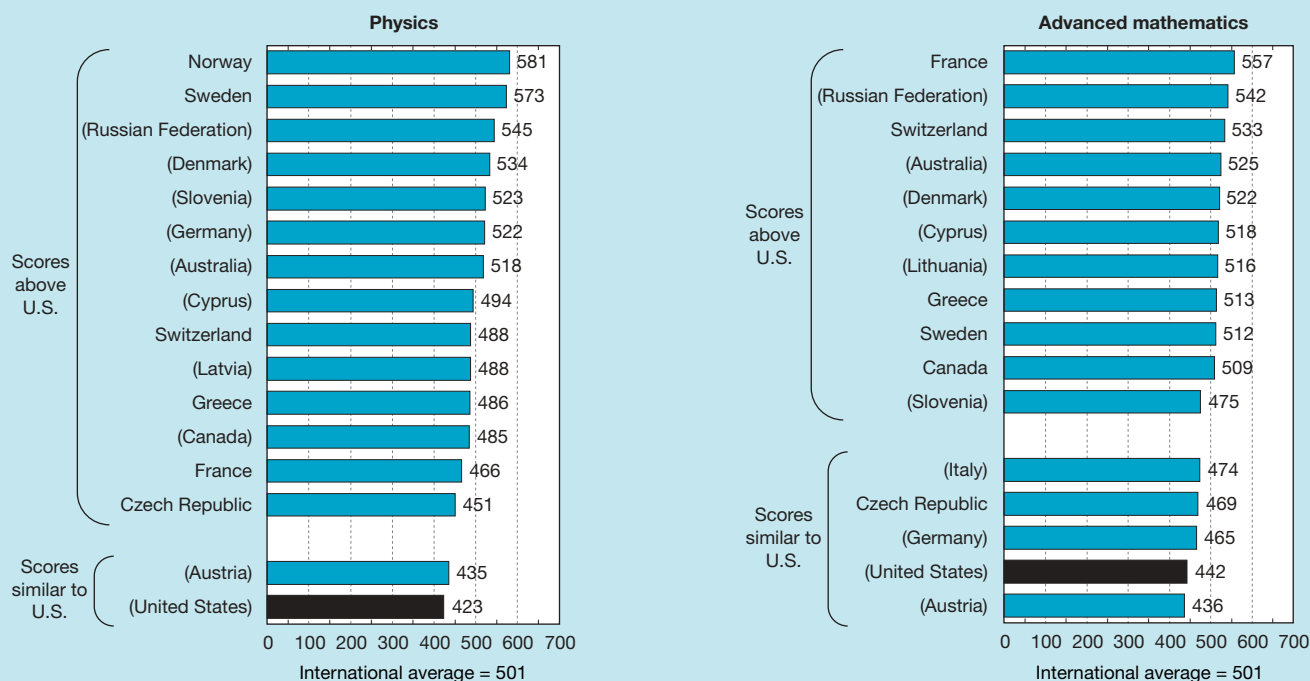


Figure 1-6.

Average scale score on TIMSS physics and advanced mathematics assessment for students in final year of secondary school: 1994–95



TIMSS = Third International Mathematics and Science Study.

NOTE: Countries not meeting international guidelines are shown in parentheses.

SOURCE: I. Mullis, M. Martin, A. Beaton, E. Gonzalez, D. Kelly, and T. Smith. *Mathematics and Science Achievement in the Final Year of Secondary School: IEA's Third International Mathematics Study (TIMSS)* (Chestnut Hill, MA: Boston College, TIMSS International Study Center: 1998).

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relevant age cohort) performed similarly to 10 to 20 percent of the age cohort in most of the other countries. In other words, U.S. calculus students performed at a level similar to a number of other countries, although the percentage of the relevant age cohort (e.g., 17-year-olds) taking the test was significantly lower than in other countries.

Summary of International Assessment Results

Data from TIMSS and TIMSS-R show that U.S. students generally perform comparatively better in science than in mathematics; that students in the primary grades demonstrate the strongest performance, especially in science; that students in grade 8 show weaker performance; and that those in grade 12 show weaker performance still, relative to their counterparts in other countries. Furthermore, while the United States tends to have fewer young people taking advanced math and science courses, students that do take them score lower on assessments of advanced mathematics and physics than do students who take advanced courses in other countries.

Science and Mathematics Coursework

Concerns about both the content and lack of focus of the U.S. mathematics and science curriculum, both as it is stated in state-level curricular frameworks and how it is implemented in the classroom, have appeared in major studies since the early 1980s (NCES 2000d). In 1983, the National Commission on Excellence in Education concluded that the curricular “smorgasbord” then offered in American schools combined with extensive student choice explained a great deal of the low performance of U.S. students (National Commission on Excellence in Education 1983).

Since the publication of *A Nation At Risk* nearly 20 years ago, most states have increased the number of mathematics and science courses required for high school graduation as a way to address this concern. A number of states and districts have also implemented “systemic” or “standards-based” reform efforts in order to align curricular content with student testing and teacher professional development. (See sidebar, “The NGA Perspective on Systemic, Standards-Based Reform”). This section examines state-level changes in curricular requirements, as well as changes in student course-taking patterns. While the impact of these changes on student performance is uncertain, it is clear that more students are taking advanced mathematics and science courses than they were two decades ago.

Changes in State-Level Graduation Requirements

As of 2000, 25 states required at least 2.5 years of math and 20 states required 2.5 years of science; in 1987, only 12 states required that many courses in math and only 6 states

The NGA Perspective on Systemic, Standards-Based Reform

According to the National Governors Association (NGA), systemic, standards-based education reform centers on the premise that all students can achieve at high levels and is based on rigorous academic standards for student learning. This is a comprehensive approach that aligns numerous educational policies, practices, and strategies, including:

- ♦ **Content standards**—standards that reflect subject-matter benchmarks;
- ♦ **Performance standards**—standards that clarify the benchmarks to be obtained;
- ♦ **Student assessments**—tests that measure student performance against content and performance standards;
- ♦ **An accountability system**—a system that monitors student and school performance;
- ♦ **Teacher preparation**—licensure requirements that permit someone to teach;
- ♦ **Professional teacher development**—activities that provide continued learning opportunities;
- ♦ **A governance structure**—a structure that defines how decisions are made; and
- ♦ **Public support**—tools that help the public understand the education reforms.

The premise underlying systemic, standards-based reform is that rigorous academic standards make achievement expectations clear. In principle, standards detail what students should know and be able to do in various subjects at each grade level or at specified benchmark grade levels. High-quality assessments can then measure student progress toward meeting the standards and provide parents, teachers, and policymakers with information about student progress. A strong accountability system is one that holds schools, educators, and students accountable for making sure students achieve the established standards. A solid system also recognizes high-performing or improving students and schools for their success and provides assistance and guidance to struggling students and schools.

SOURCE: National Governor's Association Center for Best Practices, n.d.

required that many courses in science. A survey of states conducted by the Council of Chief State School Officers (CCSSO) in 2000 showed the following state totals for required credits in mathematics and science (CCSSO 2000a):

- ♦ Twenty-one states required between 2.5 and 3.5 credits of mathematics and four states required four credits.
- ♦ Sixteen states required between 2.5 and 3.5 credits of science and four states required four credits.
- ♦ Five states left graduation requirements to local districts.

The National Education Commission on Time and Learning (NECTL) cites research indicating positive effects of strengthened graduation requirements. As schools offered more academic courses, particularly in mathematics and science, more students, including minority and at-risk students, actually enrolled in the courses (National Education Commission on Time and Learning 1994). Data from high school transcripts collected by NCES support this finding. Students took more advanced science and mathematics courses in 1998 than did students who graduated in the early 1980s (NCES 2001c). In 1998, almost all graduating seniors (93 percent) had taken biology, and more than one-half (60 percent) had taken chemistry. (See figure 1-7 and text table 1-5.) In comparison, 77 percent of 1982 seniors had completed biology and 32 percent had completed chemistry. In the class of 1998, more than one-quarter (29 percent) of graduates had completed physics compared with 15 percent of 1982 graduates. Participation rates in AP or honors science courses are considerably lower: 16 percent for biology, 5 percent for chemistry, and 3 percent for physics (NCES 2001c).

In 1998, more graduating students had taken advanced mathematics courses than did their counterparts in the early 1980s (see figure 1-7). In 1998, 62 percent of students had taken algebra II compared with 40 percent in 1982. The 1998 participation rates for geometry and calculus were 75 percent and 11 percent, respectively. Corresponding figures for 1982 were 47 percent in geometry and 5 percent in calculus. The percentage of graduates taking AP calculus rose from 1.6 to 6.7 percent over the same period (NCES 2001c).

From 1982 to 1998, there was a corresponding decrease in the percentage of graduates who took lower level mathematics courses. For example, the average number of Carnegie units in mathematics earned by graduates increased from 2.6 to 3.4 between 1982 and 1998, but the average number of units earned in courses at a lower level than algebra declined from 0.90 to 0.67 (NCES 2001c).⁶

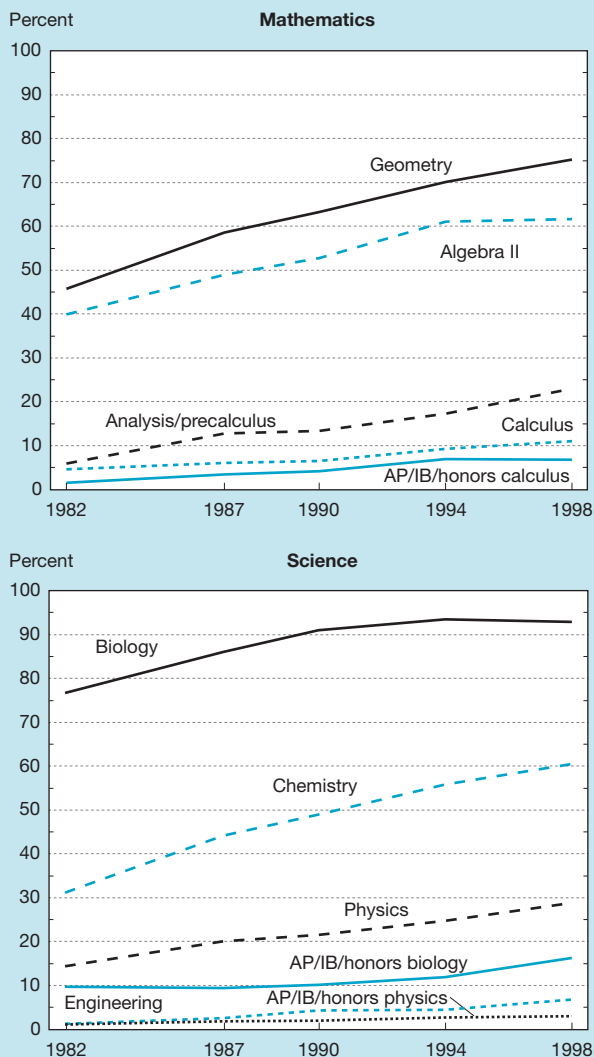
Differences in Course Participation by Sex

Given the established association between courses taken in high school and later educational outcomes (J. Smith 1996; Sells 1978), the lower representation of females throughout the science, mathematics, and engineering pipeline has been

⁶ The Carnegie unit is a standard of measurement that represents one unit of credit for the completion of a one-year course.

Figure 1-7.

Percentage of high school graduates who took selected mathematics and science courses: 1982, 1987, 1990, 1994, and 1998



AP = Advanced Placement; IB = International Baccalaureate

SOURCE: National Center for Education Statistics, *The 1998 High School Transcript Study Tabulations: Comparative Data on Credits Earned and Demographics for 1998, 1994, 1990, 1987, and 1982 High School Graduates*, NCES 2001-498, Washington DC: U.S. Department of Education, Office of Educational Research and Improvement: 2001a.

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a cause for concern. Therefore, there has long been an interest in tracking sex differences in the patterns of advanced mathematics and science courses taken in high school.

Both female and male students are following a more rigorous curriculum than they were two decades ago, and female graduates in 1998 were more likely than males (58 versus 53 percent) to have completed the “New Basics” curriculum, composed of four units of English and three units each of science, social studies, and mathematics, as recommended in *A Nation At Risk* (NCES 2000b). Comparison of the transcripts of high school graduates indicates that female and male students have broadly similar coursetaking patterns, although

there are some differences. Female students are as likely as males to take advanced math and science courses but are more likely to study a foreign language. Between 1982 and 1992, the percentage of both female and male graduates who took advanced mathematics and science courses in high school increased, although for many subjects parity between the sexes had been attained by 1982 (NCES 2000b). In the class of 1998, females were less likely than males to take remedial mathematics in high school but at least as likely as their male peers to take upper level mathematics courses such as algebra II, trigonometry, precalculus, and calculus. (See figure 1-8 and text table 1-5.) With respect to science, females were more likely than males to take biology and chemistry. Females have continued, however, to be less likely than males to take physics (NCES 2000b).

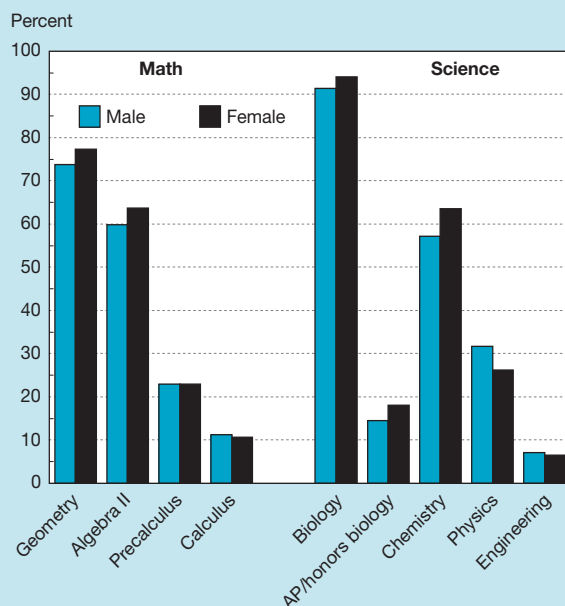
Research has shown that once females begin science courses, they are taught similar amounts of science and receive grades similar to (or better than) those of their male counterparts (Hanson, Schaub, and Baker 1996; Baker and Jones 1993; DeBoer 1984).

Differences in Course Participation by Race/Ethnicity

Students from racial/ethnic groups that are typically underrepresented in science have made substantial gains in both the total number of academic courses taken in high school and in the number of advanced mathematics and science

Figure 1-8.

Percentage of 1998 high school graduates who took selected mathematics and science courses in high school, by sex



SOURCE: National Center for Education Statistics, *Trends in Educational Equity of Girls and Women*, NCES 2000-030 (Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement: 2000h).

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Text table 1-5.

High school graduates who completed selected mathematics and science courses in high school, by sex and race/ethnicity
(percentages)

Courses (Carnegie units)	1998											
	1982	1987	1990	1994	Total	Male	Female	Race/ethnicity				
								White	Black	Hispanic	Asian/ Pacific Islander	American Indian/Alaskan Native
Mathematics ^a												
Any mathematics (1.0)	98.5	99.0	99.9	99.8	99.8	99.8	99.8	99.8	99.9	99.8	100.0	99.7
Algebra I (1.0) ^b	55.2	58.8	63.7	65.8	62.8	62.0	63.6	63.5	62.3	61.4	56.8	63.3
Geometry (1.0)	47.1	58.6	63.2	70.0	75.1	73.7	77.3	77.7	72.5	62.3	75.9	57.2
Algebra II (0.5) ^c	39.9	49.0	52.8	61.1	61.7	59.8	63.7	64.6	55.6	48.3	70.1	46.6
Trigonometry (0.5)	8.1	11.5	9.6	11.7	8.9	8.2	9.7	10.0	4.8	5.6	11.7	5.5
Analysis/precalculus (0.5)	6.2	12.8	13.3	17.3	23.1	23.1	22.8	25.0	13.8	15.3	41.3	16.4
Statistics/probability (0.5)	1.0	1.1	1.0	2.0	3.7	3.4	3.9	4.3	2.1	1.7	3.8	3.7
Calculus (1.0)	5.0	6.1	6.5	9.3	11.0	11.2	10.6	12.1	6.6	6.2	18.4	6.2
AP/IB calculus (1.0)	1.6	3.4	4.1	7.0	6.7	7.3	6.4	7.5	3.4	3.7	13.4	0.6
Science												
Any science (1.0)	96.4	97.8	99.3	99.5	99.5	99.5	99.6	99.5	99.3	99.3	99.4	99.4
Biology (1.0)	77.4	86.0	91.0	93.2	92.7	91.4	94.1	93.7	92.8	86.5	92.9	91.3
AP/IB honors biology (1.0)	10.0	9.4	10.1	11.9	16.2	14.5	18.0	16.7	15.4	12.6	22.2	6.0
Chemistry (1.0)	32.1	44.2	48.9	55.8	60.4	57.1	63.5	63.2	54.3	46.1	72.4	46.9
AP/IB honors chemistry (1.0)	3.0	3.5	3.5	3.9	4.7	4.9	4.7	4.8	3.5	4.0	10.9	0.9
Physics (1.0)	15.0	20.0	21.6	24.5	28.8	31.7	26.2	30.7	21.4	18.9	46.4	16.2
AP/IB honors physics (1.0)	1.2	1.8	2.0	2.7	3.0	4.0	2.1	3.0	2.1	2.1	7.6	0.9
Engineering (1.0)	1.2	2.6	4.2	4.5	6.7	7.1	6.5	7.9	4.8	2.3	5.2	9.6
Astronomy (0.5)	1.2	1.0	1.2	1.7	1.9	2.4	1.5	2.4	0.9	0.8	1.0	2.1
Geology/earth science (0.5)	13.6	13.4	24.7	22.9	20.7	21.5	20.1	21.5	24.2	15.9	9.5	21.7
Biology and chemistry (2.0)	29.3	41.4	47.5	53.7	59.0	55.4	62.3	62.0	53.0	43.7	69.5	43.2
Biology, chemistry, and physics (3.0) ...	11.2	16.6	18.8	21.4	25.4	27.4	23.7	27.6	17.4	15.9	40.2	14.2

AP = Advanced placement; IB = International Baccalaureate

^aData include only percentage of students who earned credit in each course while in high school and do not count those students who took these courses before entering high school. Many students now take algebra I in 8th grade.

^bExcludes prealgebra.

^cIncludes algebra II/trigonometry and algebra II/geometry.

NOTE: A Carnegie unit is a standard of measurement that represents one unit of credit for the completion of a one-year course.

SOURCES: National Center for Education Statistics, *Digest of Education Statistics 2000*, table 140, NCES 2001-034, (Washington DC: U.S. Department of Education, Office of Educational Research and Improvement, 2001b).

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courses taken, although the range in coursetaking patterns remains wide. The emphasis on academic coursetaking is reflected by the increase in the percentage of high school graduates in all racial/ethnic groups taking the “New Basics” curriculum. The proportion of 1998 high school graduates who took this core curriculum ranged from about 40 percent for Hispanics and American Indians/Alaskan Natives, to 56 percent for blacks and whites, to 66 percent for Asians/Pacific Islanders. This is a substantial increase from 1982, when only 14 percent of graduates took this stringent curriculum (NCES 2001c).

Students in all racial and ethnic groups are taking more advanced mathematics and science courses, although black, Hispanic, and American Indian/Alaskan Native graduates still lag behind their Asian/Pacific Islander and white counterparts in advanced mathematics and science coursetaking. For example, the percentage of graduates in the class of 1998 who had taken algebra II ranged from 47 percent of American In-

dians/Alaskan Natives to 70 percent of Asians/Pacific Islanders. Percentages for white, black, and Hispanic graduates were 65, 56, and 48 percent, respectively. (See text table 1-5.) Furthermore, Asians/Pacific Islanders were a third more likely than whites to take calculus (18 versus 12 percent) and approximately three times more likely than blacks, Hispanics, and American Indians/Alaskan Natives (about 6 percent each). Also, although 46 percent of Asian/Pacific Islander graduates took physics in high school, blacks, Hispanics, and American Indians/Alaskan Natives were less than half as likely to do so (NCES 2001c). From a coursetaking perspective at least, it appears that all racial and ethnic groups are better prepared for college today than they were in the early 1980s, although blacks, Hispanics, and American Indians/Alaskan Natives are less prepared than their Asian/Pacific Islander and white peers.

Both prior achievement and peer choices appear to strongly influence coursetaking in high school. Although some researchers have found that minority and low socioeconomic

status (SES) students are more likely to be assigned to lower curriculum tracks in high school, even after ability is held constant (Oakes 1985; Rosenbaum 1980, 1976), others have found that verbal achievement scores and the expectations and guidance of others (parents, teachers, guidance counselors, and peers) are influenced by race and SES and that these mediating variables then influence track placement (Cicourel and Kituse 1963; Rosenbaum 1976; Erickson 1975; Heyns 1974). Fordham and Ogbu (1986) argue that one major reason black students do poorly in school is that they experience inordinate ambivalence and affective dissonance with regard to academic effort and success. They argue that because of these social pressures, many black students who are academically able do not muster

the necessary perseverance in their schoolwork. (See sidebar, “Advanced Placement Test Results.”)

Impact of Coursetaking on Student Learning

On balance, it appears to be too early to draw general conclusions about the quality of either the new courses required in state-level curriculums or the advanced mathematics and science courses that more and more students are taking. Studies of “dilution” of course content are mixed and not uniform across all students. Moreover, many of these studies were conducted in only a handful of states and school districts and for only a handful of courses, with the earlier studies having

Advanced Placement Test Results in Urban Schools

A recent study by the Council of the Great City Schools (GCS), titled *Advancing Excellence in Urban Schools: A Report on Advanced Placement Examinations in the Great City Schools*, examined advanced placement (AP) coursetaking patterns and subject test results in America’s urban schools. The council conducted the analysis in collaboration with the College Board, which offers AP courses and exams in 33 subjects. Findings were based on approximately 38,000 AP test results from 58 GCS districts in the spring of 1999. Results showed that:

- ◆ Mean AP test scores for GCS students were more likely to be below the 3.0 needed to earn college credit than were the scores of students nationally, whose mean AP test scores were slightly above 3.0.
- ◆ African American GCS students were more likely to take AP exams in English language, biology, and English literature; they were least likely to take calculus BC and physics C (electricity and magnetism) exams.
- ◆ Hispanic GCS students were most likely to take English literature, calculus AB, and physics B exams; they were least likely to take calculus BC and computer science A exams.
- ◆ Asian American GCS students were most likely to take calculus BC and physics C (electricity and magnetism) exams; they were least likely to take AP exams in English language and English literature.
- ◆ GCS students posted their highest average AP scores in calculus (3.3) and lowest average scores in physics and chemistry (2.2).
- ◆ GCS students who had taken more core courses outscored those who had taken fewer core courses. For this study “core” academic preparation was defined as the courses in each content area that many college admissions officers use to determine proper academic preparation for an incoming first-year college student. For example, the core includes three years of mathematics, such as one year credit each for Algebra 1, Algebra 2, and Geometry and one-

half year credit each for Trigonometry, Calculus (not Pre-calculus), other mathematics courses beyond Algebra 2, and Computer Mathematics/Computer Science. The core also includes three years of science reasoning, such as one year credit each for General/Physical/Earth Science, Biology, Chemistry, and Physics.

- ◆ Nationally, students with core or more academic preparation attained higher AP subject test scores than GCS students with similar academic preparation. African American test-takers in the GCS were less likely to have taken core courses in Biology and Chemistry than all other racial groups in the GCS. Hispanic test-takers in the GCS were more likely to have taken core courses in Chemistry than all other racial groups in the GCS.
- ◆ AP scores nationally and in GCS were strongly related to family income. Students nationally outscore their GCS counterparts at each household income bracket. The only GCS students who had average scores of 3.0 or above in any AP subject were those with household incomes greater than \$80,000.
- ◆ White students were likely to outperform other students nationally and in GCS. White students in the national sample had higher AP subject test scores than their white counterparts in the GCS. African American students in the GCS scored lower than their counterparts in the national sample.

The Council of the Great City Schools consists of 57 urban school districts (out of 16,411 in the United States) and enrolls about 14 percent of the students attending U.S. public schools. These districts serve a larger proportion of minority students than the national average (73 percent of students were black or Hispanic in 1999), and the majority are poor (63 percent are free-lunch eligible compared with 35 percent of students nationally).

SOURCE: Council of the Great City Schools (CGCS) and the College Board. 2001. *Advancing Excellence in Urban Schools: A Report On Advanced Placement Examinations in the Great City Schools*. Washington, DC <http://www.cgcs.org/reports/home/ap_1999.htm> and Key Facts: 1997–98 Data About Council Member Districts <<http://www.cgcs.org/reports/data/index.cfm>>.

been conducted not long after the increased requirements were enforced. Thus, there may have been little opportunity for revisions and improvement.

Several studies point to possible negative effects of stronger coursetaking requirements. For example, minority and at-risk students failed more courses than they did before stronger mandates were put into practice (NECTL 1994). Opinions differ on the quality of the additional courses taken, especially those taken by low-achieving students. There has been particular concern about the quality of new mathematics courses designed for low achievers, who, under a traditional curriculum, would have taken general or basic mathematics. Research suggests that implementation of state-level mandates for stronger coursetaking requirements varies greatly across districts and schools. Studying 18 high schools in 12 districts in 6 states, Porter, Smithson, and Osthoff (1994) found some schools pushing students into demanding content in higher level course while others did not. Furthermore, Gamoran (1997) found that bridging courses, those designed to prepare lower achieving students for college-preparatory courses, achieved some success in improving student achievement. Research in this area is inadequate, however, for evaluating whether or not the increase in state-level curricular requirements have changed the level of difficulty or quality of mathematics and science courses offered to students.

Additional studies accessing the content of the mathematics curriculum, as well the quality of 8th grade mathematics instruction, are described in the section on Curriculum and Instruction. Strengthening course-taking requirements is only one component of most educational reform strategies, however. The next section examines states' attempts to implement state-wide curricular frameworks, as well as assessments of the underlying content.

Content Standards and Statewide Assessments

In the 1980s, most states approved policies aimed at improving the quality of K–12 education, implementing statewide curriculum guidelines and frameworks as well as assessments. At present, half of the states require students to pass some form of exit examination to graduate from high school, and others report developing such tests (CCSSO 2000a). Underlying this reform agenda is the assumption that these standards and assessments will lead to higher student achievement. However, assessments and standards are not always tightly linked, and the implied performance incentives for students, teachers, and administrators vary across states. Furthermore, there is concern that some state-level assessments focus too much on facts, even though the associated standards call for complex scientific inquiry. This section reviews the national data available concerning the implementation of standards and assessments across states. Particular attention is paid to the alignment of these new standards and assessments to student achievement by reviewing recent research in this area.

Adoption of Content Standards

State-level content standards are typically intended to provide the basis for state and local decisions on curriculum, texts, instructional materials, student assessments, teacher preparation and professional development, and other components of programs of instruction (CCSSO 2000a). CCSSO reported that, by 2000, 49 states had established content standards in mathematics and 46 states had established standards in science (CCSSO 2000a). Teachers remain concerned, however, that standards do not always provide clear guidance regarding the goals of instruction and that schools do not yet have access to top-quality curriculum materials aligned with the standards (Achieve 2000). The next section highlights some issues regarding the degree to which states require or facilitate the alignment between instructional materials and standards.

Statewide Policies on Textbooks and Standards

One way that states can influence the implementation of mathematics and science standards is to select or recommend textbooks and curriculum materials for schools that are aligned with their standards. Fewer than half of the states, however, mandate or recommend particular textbooks and curriculum materials. The Council of Chief State Officers reported that a total of 21 states had a state policy regarding textbooks and curriculum materials for classrooms, as of spring 2000 (CCSSO 2000a). Among the total, 11 have a state policy defining state selection of textbooks and materials to be used and another 10 recommend texts or materials to the local districts. In 2000, 20 of the 21 states with a textbook policy use their state content standards to select or recommend curriculum materials, the same as in 1998.

Some examples of state policies on textbooks include California, where content standards and frameworks are used to select the materials that will be adopted by the State Board of Education and recommended to school districts and Tennessee, where the state adopts an approved list of curricular materials from which local schools boards may then choose and receive state funds. These policies contrast with those of Alaska and New Jersey, where textbook selection decisions are left up to the local boards. As noted above, most states do not have a statewide policy on aligning textbooks and standards (CCSSO 2000a). (See sidebar, “States Band Together to Create a Market for Standards-Based Materials”).

State Assessment Programs in Mathematics and Science

Nearly all states conduct statewide assessments in mathematics, although the grades assessed and the type of test vary widely. Results of the most recent CCSSO Annual Survey of State Student Assessment Programs (for the 1998/99 school year) show that 48 states have a statewide program in one or more subjects (CCSSO 2000a). Although many states have administered statewide assessments of student learning since the 1970s, additional states approved policies requiring